INTRODUCTION

Motivation
- Falls impact the economy negatively, costing over $150 billion each year [1].
- Falls also negatively impact the society, by continually being amongst the top causes of the fatal injuries in the US work places [2].
- Sagittal angular momentum ($H$) is a quantity representing the movement of rotation of an object.
- Previous studies [3] indicated that severe slipppers, who are more prone to fall [4], had significantly higher $H$ following a slip, compared to mild slippers. The two severity groups also deviated in their COM height (COM$_h$) and Single/Double Stance duration (SS/DS) (Fig. 2)[3, 5].

Objectives
- To compare the time lead/lag between the deviations observed in COM$_h$, $H$, and single support duration to rule out or substantiate causal relationships.

Hypotheses
- We hypothesize that a time-lead over COM$_h$ would substantiate a causal relationship between deviations in $H$ and severe slipping, and hence, falling.

METHODS

Subjects
- Twenty healthy young adults (age (mean±SD)=23.6 ± 2.52) participated in this study upon signing a written consent. There were 11 males and 9 females and excluded in case of history of gait disorders.

Procedures
- Participants were asked to walk at their comfortable speed in a long walkway. Subjects wore a harness system throughout the experiment.
- Subjects performed four “practice walking trials” getting familiar with the setup. Then, a slippery contaminant was applied to the walkway without informing the subjects.

Data Collection
- Markers’ data during normal walking and slipping were collected for analysis.
- COM$_h$ was calculated by weighted-averaging limbs’ distances and masses.
- $H$ was measured via multiplying each limb’s mass, velocity, and angular velocity to its distance and moment of inertia, respectively, as it follows: $H = \sum_{i=1}^{n} m_i (r_{com,i} \times v_{com,i}) + I_{i}\omega_i$
- The gait cycle duration was normalized to 100 points for all subjects, and the slipping behavior was converted to 30 points (i.e. % gait cycle). The support duration analysis was done for 75% instead of 30% post-slipping (Fig. 2c).
- COM$_h$ and $H$ were normalized to subject’s weight, height, and speed.
- Subjects were classified as severe slippers if their Peak Heel Speed (PHS) during slipping exceeded 1.44 m/s [4].
- Independent t-test was used to find inter-group differences and time sequence of deviations examined.

RESULTS

- Mild slippers (12 persons) and severe slippers (8 persons) were no different during the walking but were different in all tested variables upon slipping.
- Severity groups differed in COM$_h$ from 24% to 30% after slip initiation (p-value<0.05, Fig. 2a).
- Severe slippers showed higher $H$ post-slipping (from 3% to 27%) (p-value<0.001, Fig. 2b).
- Mild slippers had normal SS phase while all severe slippers had a shortened SS (p-value<0.001) and placed their swing limb on the floor after slipping (“toe-touch” behavior).

DISCUSSION and CONCLUSION

- The time lead of the deviations in $H$ over COM$_h$ suggests that the excessive rotation of the body, (i.e. higher $H$), causes the drop in COM$_h$ rather than a direct vertical collapse on the legs.
- Toe-touch could be a measure to constrain and lower $H$, since $H$ can only be changed via a torque around the body’s COM by the swing limb.
- $H$ may be a key variable in controlling slips: The CNS may choose to change its control method and incorporate the toe-touch response as a measure to re-establish the balance, or even take a safer fall depending on how high $H$ value is. Future studies should further investigate the causality of $H$ to falls.

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References
1. Florence et al., MMWR, 2013.